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ATTENTION AND THORACIC BREATHING.

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This paper contains a statistical study of data experimentally obtained in regard to the correlation between changes in thoracic breathing and changes in attention. In calling the study "statistical," the writer has two characteristics in mind. In the first place, the results presented consist of records taken from many experimental subjects, a few to each subject, and not of records taken from a few well-trained observers who served as subjects repeatedly. In the second place, the control of the experimental conditions was not so secure as to enable the ex-

[1]The writer was assisted in an important, though minor degree by the following students: L. J. Boynton, H. S. Wheeler, and M. B. Woodbury, graduates; and E. M. Bennett, Maud Dewar, Lillian Dixon, A. S. Carlisle, M. E. Cooke, G. C. Hanna, M. C. Hunt, Frances Warren, and Edith Young, seniors. The writer supervised the experiments, served as one of the subjects in Groups 1 and 4, and compiled all the tables which appear in this paper. The students named made the experiments, computed the breathing-rates upon which Tables 2 and 3 are based, and inspected the individual kymograph-tracings to determine the changes in amplitude and expiratory pause upon which Tables 1 and 4 are based. The results as to rate obtained by each different set of student experimenters have been averaged separately by the writer to ascertain the presence of any divergence which might unfit them for being averaged together. No such divergence exists. The organ music of Group 3 was furnished by Dr. Hamilton C. Macdougall, professor of music at Wellesley College. The experiments of this group, considered in another connection, constitute part of an investigation now pursued by Professor Macdougall with the assistance of the writer. The investigation here reported extends from the January of 1900 to the spring of 1904.

perimenters to dream that variations in the results would fall under the scientific "law of error." The experimental condition is the nature of the subject's attention, high and steady as in arithmetical computation, high and unstable as in keen annoyance, low and wavering as in moments of complete idleness, or whatever it may be. The experimental results are such changes in his thoracic breathing as may occur *pari passu* with changes in the degree and steadiness of his attention. As regards the experimental condition, the experimenters merely assume that a given method of attracting and holding the attention—as, for example, a sum dictated in mental arithmetic —produced much the same kind and degree of attention in the *majority* of cases. As regards the experimental results, the compiler of this report claims simply that they manifest certain *tendencies* in the majority of subjects to breathe in a given manner under a given condition, precisely as statistics in regard to phthisis show a greater *tendency* to this disease in state-prisons than among the general population.[1]

The investigation was suggested by the paper of Professor James R. Angell and Dr. Helen B. Thompson upon the correlation of changes in respiration and circulation with changes in consciousness.[2] These investigations made "two very complete series of tests on two different subjects," and "less extended observations upon a number of different subjects." The special object of the investigation here reported was to obtain such evidence for or against the Angell-Thompson conclusions as might be obtained from the massed results of tests of thoracic breathing taken from a large number of young persons. The subjects included in round numbers one hundred and twenty college girls of no profound psychological information and fifty boys and girls between the ages of four and eleven.

For purposes of comparison two other sets of records are introduced, representing on the one hand, greater introspective ability, and on the other, lower conscious development. These records include (1) the results of tests made upon the writer and a senior-student, who shared in the investigation, during genuinely absorbing games of duplicate whist played with keen and accustomed rivals, and (2) the results of somewhat fragmentary tests upon two frightened cocker spaniels.

As a supplement to other studies, the special value of the evidence here presented consists precisely in the facts (1) that the tests were made upon so many different subjects a few to each subject, and (2) that so large a number of the subjects

[1] On this use of the word "statistical," compare Ebbinghaus, Ueber das Gedächtniss, pp. 18-20.

[2] "Organic Processes and Consciousness, *Psychological Review*, 1899, pp. 32-69.

were mentally immature. The advantage of experimenting upon untrained subjects, whether children or adults, is the following: It is true not only that respiration, unlike circulatory phenomena, is largely under voluntary control, but also that in a pneumographic test the attention of the subject is necessarily called to his breathing by the nature and position of the apparatus. There is, therefore, great danger both that the subject of scientific training will breathe according to theoretical considerations—or will try not to do so, which is quite as bad—and that the alert adult who is tested many times over will breathe according to past self-observations. This risk is avoided when average or when typical results from a large number of untrained subjects are secured. An additional advantage in the case of children is the fact (recognized by Binet) that they may be roused to very real emotions, even under laboratory conditions. In this investigation, genuine emotion was very rarely secured except in the case of the children, the whist-players, and the dogs.

On the other hand, and as against the force of the main body of our evidence, these two considerations must be admitted: first, that the child cannot check by any introspective accounts of his own, the experimenter's assumptions as to his experiences under the varied experimental conditions, and second, that any subject who is tested only twice, for scarcely more than half an hour at a time, will never rid himself of a certain self-conscious curiosity in regard to the experiment. He will not, indeed, of set purpose adopt or avoid a certain manner of breathing, but he will never breathe normally in the sense of breathing as he would under the various conditions minus the tell-tale apparatus. It is probable that one does not often secure records of really normal breathing even from the much-tested subject; it is certain that one never does so from the raw recruit. In full recognition of these considerations, these results are presented as a supplement to other studies—a supplement which has most decidedly the defects of its virtues.

As already stated the primary purpose of the investigation here reported was to verify so much of the conclusion of Professors Angell and Thompson as refers to respiration. The exact scope of the study may be indicated by noting the nature of this conclusion and by enumerating, on the one hand, the changes in attention and, on the other, the changes in breathing which have been taken into account. The two sets of changes, if one may reiterate, stand to each other as experimental conditions stand to experimental results. In connection with the statement of attention-changes, it will be convenient to outline the expedients used to secure them; and in connection with the statement of breathing-changes, to describe the apparatus em-

ployed in registering them and the method by which the statistics were compiled from the graphic records.

In the following paragraph Professors Angell and Thompson formally state their thesis in regard to the correlation between circulation and respiration on the one hand, and consciousness on the other: "When the attentive process runs smoothly and uninterruptedly, these bodily activities progress with rhythmic regularity. Relatively tense, strained attention is generally characterized by more vigorous bodily accompaniments than is low-level, gentle, and relatively relaxed attention (of drowsiness, for instance); but both agree, so long as their progress is free and unimpeded, in relative regularity of bodily functions. Breaks, shocks, and mal-coördinations of attention are accompanied by sudden spasmodic changes and irregularities in bodily processes, the amount and violence of such changes being roughly proportional to the intensity of the experience." In constituting a "hierarchy" of psychological conditions as representing "increasing stability of attention," the authors put at one end of the scale, the profound emotions, and at the other, sustained attention to continuous sensations, and mental application (such as mental calculation under favorable conditions), and many cases of non-emotional revery, such as the revery of drowsiness.

In guarding their position, the authors write: "It should not be understood that we dogmatically deny any constancy of changes apart from the form of constancy we emphasize, although such constant conditions are rare. We simply maintain that from our observations the only feature which appears essentially constant under *all psychological* conditions is the relative stability or instability (of the dynamic type) which these organic activities manifest in connection with the different processes of attention."

Briefly, then, the conclusion to be tested is this: The correlation between regular breathing and stable attention and between irregular breathing and unstable attention, is the only essentially constant correspondence between respiration and consciousness. In view of the history of opinion upon the point in question, it will be necessary in verifying this thesis, to show not only that (1) the correlation stated is "essentially" constant but also (2) that there is a much less constant correspondence between opposite features of breathing and either (a) high-level and low-level attention or (b) antithetical affective states.[1] The correlation between a change of breathing and a

[1] *Cf.* Angell and Thompson, *op cit.*, last sentence on p. 44 and second note on p. 45. An excellent summary of results previously obtained in regard to the relation between organic processes and consciousness is given by these writers.

change of attention may perhaps be considered as essentially constant if the breathing-change occurs in a goodly majority of the cases in which the attention-change is scheduled to occur. A large number of negative instances can always be explained on the supposition that the means taken to control the attention failed of doing so.

The procedure here reported was scaffolded upon the cross-division of attention as stable and unstable, high-level and low-level. In other words, the variations sought were two-fold: (1) variations in stability and (2) variations in degree. An attempt was made systematically to secure for comparison cases (1) of low and unstable attention, (2) of low and stable attention, (3) of high and unstable attention, and (4) of high and stable attention. Expedients to secure high-level and unstable attention were divided between attempts to secure pleasurable and attempts to secure unpleasant excitement.

Before detailing the expedients employed to secure these varieties of attention, it seems desirable to define more exactly the terms "stability" and "degree" (or "level") as here applied to the attention. By the writer, attention is understood to be great in degree or high in level when there is a maximal difference in clearness between the "focal" and the "marginal" contents of consciousness. It is understood to be stable when each focalized content gradually gives place to the next without sudden blurring or abrupt transition. Great stability and a great degree of attention do not necessarily go together although attention can be both great and stable; as it is, for example, in rapt attention to music or in unhesitating literary composition. In fact, attention which is great in degree tends, because it offers strong resistance to distraction, to be stable also. In virtue of its interest, primary or acquired, the train of ideas attended-to not only stands in clear relief but persists. Nevertheless, in an absence of distraction, attention may be *stable without being great*, as for instance, in reading "David Copperfield" for the tenth time. Moreover, in strong emotion, attention may be *great without being stable*. In violent anger, for example, there is a kaleidoscopic shifting of various phases of the exasperating situation even while all ideas irrelevant to this situation are blurred or inhibited. This high-level but unstable attention cannot indeed exist except in emotional excitement since only by the competition of high affective values in various phases of the situation can resistance to distraction be so overcome as to allow this oscillation. On the other hand, high-level attention if unstable, must be more unstable than low-level attention can ever be, since the higher the level, and the sharper the focus of the content attended-to, the wider must be the swing, the more violent the shift, which brings

any other content into prominence or focus. For illustration, compare the catastrophic changes of rage, in which one is fully occupied now in imaging the consequences of the offence, now in picturing the offender, and now in enduring one's own suffocating chest and throat sensations, with the easy shifts of attention by which in walking along the street on a March afternoon one notes first the coldness of the wind, then the odor of hyacinths from a florist's shop, then the cakes in a baker's window, and then the strains of a hurdy-gurdy. In the latter case, the content-transitions are as abrupt as possible, but consciousness does not seem at one instant all cakes and at the next all hurdy-gurdy.

Attention which is both great in degree and also highly stable,—such attention, for example, as one gives to the cards which are played in an exciting game of whist—usually involves that complex of organic sensations which we know as the "strain" or "effort" consciousness. In really stable attention, consciousness is simply tinged or flavored by this feeling of effort. There are breaks in the stability of attention if this feeling ever and anon comes into focus. When one is trying to attend to a conscious content which is extremely uninteresting, the focus will shift between this content, the strain-consciousness, and the motive for attending. But to attend to being attentive to anything is, *ipso facto*, to be inattentive to that thing. When the effort-consciousness comes into focus, the mechanism which produced it by keeping attention stable at a high level has temporarily broken down. On the other hand, a sharp fall in the level of attention as distinguished from a temporary break in its stability, is ordinarily characterized by that complex of organic sensations which we know as the "relaxation" or "relief" consciousness.

In the understanding of the writer the distinction just made between the stability and the degree or level of attention tallies with the distinction indicated by Angell and Thompson in language which has a somewhat biological ring.[1] Moreover, it would seem that the distinction between high-level and low-level attention is almost if not quite tantamount to the antithesis made by Binet and his co-workers between mental activity and mental passivity, "entre les excitations queiconque et l'état de repos physique et moral."[2]

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[1] See especially the last paragraph of their paper, p. 69.

[2] The only difficulty in this *rapprochement*, is in the classification of depressing emotion. Binet and Courtier recognize the existence of this type of emotion in their classical treatment of "La Vie Émotionnelle" (*Année Psych.*, 1896, pp. 80-82), although they had not obtained any instances for experimental purposes. This depressing emotion is antithetical to exciting emotion. But is attention in depressing emo-

An account may now be given of the experimental procedure in this investigation. In the first two of the five groups into which the experiments fall, an attempt was made to secure from every subject each of the four varieties of attention named above. In Group 1, the subjects were ninety-three college students and the writer; in Group 2, fifty children. In the following outline of experiments a device to control the attention will for convenience be called a "stimulus." To secure low-level attention no stimlus was necessary. *Low and unstable attention* is one's normal condition, and breathing-records taken during this state constitute the standard of comparison for other records. This condition was supposed to be secured when the subject sat idle, paying casual attention to the movements of the experimenters and too much affected by the novelty of the situation or by recent distraction to fall into revery.

On the other hand, cases of *low-level but stable attention* were assumed to be constituted by cases of apparently non-emotional revery. Cases of genuine revery were actually secured only from the students. For a reason which will later appear, cases in which the children sat unstimulated but absorbed must be construed as cases of high-level attention. In the students, the degree of stability in revery must have varied with the absence of distraction. In most cases, the level of attention was probably lower than when the subject sat idle but alert. The subjects were directed to "try to go to sleep."

The stimulus designed to secure *great and stable attention* was, in the case of the students, either (1) the dictation of a sum in mental arithmetic, at such a rate as to avoid both "unoccupied leisure" and "insufficient time for completing"[1] the operations, or (2) the dictation of a series of nonsense syllables, or (3) the dictation of a jingle or of a bit of poetry to be memorized, or (4) the reading of a scientific passage to be summarized. With the children this stimulus was always some form of mental calculation ranging from a simple sum in arithmetic to the counting of a few objects drawn on the blackboard.

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tion at a low or a high level? It is altogether impossible to answer this question introspectively. One may suggest, however, that "prostrating fear" and "deathly" disgust are likely to end in unconsciousness and that in incipient faintness attention is at a level anything but high. It may be added that attention-stability of the "abnormal paralytic type" (recognized by Angell and Thompson as an exception to the instability of attention in emotion) does not necessarily correspond with emotion which is depressing in Binet's sense of lowering the vital functions. Such a correspondence has yet to be proved. It should be expressly noted that the word "excitement" is not used in this paper in the physiological sense (Binet's) but as the popular equivalent for attention which is great but unstable.

[1]Angell and Thompson, *op. cit.*, p. 49.

For the most part the stimuli designed to secure from the students *great but unstable attention*, or in other words, emotional excitement, consisted in the reading aloud of certain passages from books. In many of the cases in which the stimulus was reading, an attempt was made to secure the subject's attention before the graphic record was begun. The experimenter, for example, would read in continuity for some moments beforehand or would summarize the context as vividly as possible. Nevertheless, the attempt to secure excitement by reading was a failure. Records taken during the reading of pleasurably interesting passages have been credited entirely to the score of fairly great and fairly stable attention. By reading the most distressing or revolting passages which could be used with propriety, unpleasant emotion, usually disgust, was undoubtedly secured in many cases. Nevertheless, the behavior and testimony of the subjects and the nature of the results all contribute to the conclusion that the majority of the subjects paid steady attention in spite of qualms of faintness or of the impulse to "get up and go away."

Apart from the reading, some instances of superficial emotion (Binet's *emotions psychiques volontaires*) were procured by asking the subject to "think about" the "pleasantest" or "most unpleasant" thing that had happened to her within a month. These affective reactions were cut across by the effort to recollect and were almost too feeble to be taken into account. In addition, some cases of unpleasant excitement were secured by threatening to "hurt" the subject and then actually giving her a smart prick or pinch. This expedient should have been used in a larger number of cases. A few cases of mild excitement were secured with such smells as asafœtida and pyridin. Agreeable smells were also tried but the results were altogether equivocal. Indeed, smells are obviously unsuitable stimuli on account of their direct sensorial-reflex effects upon the breathing.

With the children also, the attempt to secure pleasurable excitement was a failure, but with them the attempt to secure unpleasant excitement succeeded. Pleasure, far more genuine than was ever secured in the students, was indeed obtained by telling fairy-stories or by drawing with running comment grotesque figures of "horses" and of "lions" in bright colors on the blackboard. The small subjects, however, betrayed no excitement but rather a "riveted attention," nor can the results of the experiment be interpreted except on the supposition that the attention was extremely stable. At this point it should be noted that the breathing of the children when they were allowed for a few minutes to sit unmolested and look about them, became toward the end of this period exactly like

their breathing when they were purposely amused by the experimenters.[1] These cases were at first labeled "revery." It is obvious, however, that in them we have to do not with low-level attention but with the high-level attention involved in a keen interest in the movements of new and attractive acquaintances and in novel surroundings which had ceased to be alarming. Notwithstanding the failure of the attempt to secure pleasurable excitement, strong annoyance was actually secured (1) by pinching a finger slightly with a very formidable looking nut-cracker, or (2) by administering some bad smell (pyridin, usually), or (3) by putting drops of a grimy and sticky liquid on the hands of the girls or giving the boys, without warning, a kiss.

Thus as the actual fruitage of the first two groups of experiments, we have the following sets or sub-groups of cases or observations: first, from the students and children alike, a group of cases of normal, low-level and unstable attention, and of the high-level and stable attention involved in "mental work;" second, from the children, two groups of cases of the high-level and stable attention involved in being agreeably entertained, and a group of cases of the very great and very unstable attention involved in being sharply annoyed; third, from the students, a group of cases of the low-level but fairly stable attention involved in non-emotional revery, a group of cases of the high-level and stable attention involved in listening to pleasant reading, and a group of cases of the high-level attention with very marked individual variations in stability which is involved in listening to extremely unpleasant reading.[2] The few cases of voluntary emotions and of annoyance secured from the students by the threat and infliction of pain are not numerous enough to count as statistical groups.

In the case of the students and of the older children, attention no doubt reached its maximum of stability in the mental arithmetic. In such enforced mental application, however, there was probably as a rule no real affective equilibrium, but rather the slight unpleasantness of the strain-consciousness. In the younger children, on the contrary, attention probably reached its maximum of stability not in the task-work, about which they cared relatively little, but in the pleasurable entertainment furnished by the experimenters.

The experiments of Group 3 supplement those of Groups 1 and 2 by furnishing an additional number of instances of great

[1] See page 278 below.

[2] Even at the time these experiments were made it would have been a delicate operation to divide this set of cases into sections according to the fixity of the attention secured; at the time this paper is written, the task has become impossible.

and stable attention. The stimulus was organ-music. The subjects were twenty students. These three groups of experiments made upon many different unpracticed subjects constitute the nucleus of the investigation.

As already indicated, two other sets of data have been introduced for purposes of comparison with the main body of results. The fourth group includes the whist-tests made upon two of the investigators. The value of these experiments consists in the fact that in addition to some instances of high-level and stable attention, they offer many instances of the unstable attention implied by marked affective disturbance. Here pleasure, genuine though fleeting, was actually obtained. Thus these experiments supplement to some extent the defects of the first two groups. Moreover, we have here our best instances of a sharp and sudden fall in the attention-level with the feeling of relief which is involved in such a drop.

With the dog chiefly employed, "P.," the first records taken represent great but unstable attention, since the animal, an exceptionally nervous creature, was frightened by the apparatus, especially by the hum of the electric motor. As, however, toward the end of each sitting she relapsed into a drowsy repose in the lap of her owner, a certain number of records may be regarded as representing a fall in the attention-level and an increase in stability. The other dog, "A.," a healthier specimen, was not frightened by the apparatus after the first few moments, and was used chiefly in experiments to control the breathing-rates obtained from P. and to find a method of securing high-level and stable attention without disturbing the apparatus. So far every expedient used to attract her attention (soft whistling, the rattling of a leading-chain and so on) has produced movements of the whole body.[1]

There is one more point which it is important to note before turning from the psychological to the physiological phase of the experiments. In the first and third groups, some attempt was made at introspective control in spite of the fact that the experimenters wished the subjects to know as little as possible about the purpose of the investigation. At the end of an idleness-record the subject was desired to write down in detail what she had "thought about," and at the end of a reading or music experiment whether or not she had "listened" and how she had "liked it." From the children, of course, no such introspective check could be obtained. Yet the expression of their faces, and especially the flush produced by annoyance, served

[1] The cocker P. was in her third year when these experiments were made and weighed only thirteen pounds. A. was seventeen months old and weighed eighteen pounds.

almost as well. Nevertheless, there must remain unrevealed by the checks of introspection or behavior a very wide variation in the attention-conditions produced in different individuals by the same stimulus. Only extreme variations could be detected and only the records corresponding to them thrown out.

A few more details may, perhaps, be suggestive for demonstration experiments. At the beginning of an arithmetic or memory experiment the subject was told that she would be asked to give the answer to a sum or to recite something which would be dictated to her or to summarize something which would be read to her. She was asked, however, not to speak until she was directed to do so. The material to be memorized verbatim was read over twice with an interval of about thirty seconds between the readings. The subject was told beforehand that this would be done and was directed to recall what she could in the interval and be ready to supplement her first impression by the second reading. The following is a sample of the sums used with the students: $5 + 8 + 2 \div 3 + 15 \div 4 \times 10 \times 2 \div 50 \times 10 \div 5 \times 10 \div 5 + 8 \div 4 \times 12 \div 6 \times 2 + 4 \div 2 \times 100 \div 500$. This sort of arithmetic is, of course, incomparably easier for a bad visualizer than is the multiplication of one three-place number or even of one two-place number by another. It was believed, however, that if the task were difficult many of the subjects employed would not try to do it at all. The series of nonsense-syllables was: Raj, feg, nif, wud, fev, rem, nij, fum, hiv, tig. The "poetry" varied between Milton's "Sonnet on Blindness" and Stevenson's "Birdie with a Yellow Bill." The passage most frequently read for summarizing was Ayrton's "Practical Electricity" the first sentence of page 1 and page 2, entire. The passage most successful in sustaining amused attention was pp. 39 and 40 of the "April Baby's Book of Tunes" (by Elizabeth of the German Garden), that is, the clearing up scene after the party. The passages which produced the strongest unpleasantness were (1) the description of the plague burial-pit from "Rienzi," and (2) a part of "The Cone" in H. G. Wells's "Thirty Strange Stories," viz. pp. 312-320.

The organ music was selected for a purpose extraneous to this investigation. It was of three sorts (1) hymn-tunes, such as the familiar "Vox Dilecti," (2) two rather dismal chorals from Mendelssohn, and (3) elaborate compositions ranging from Rubenstein's "Torch-Light Dance of the Brides of Cashmere" to the Dead March in "Saul."

The procedure in the whist-experiments was as follows: The eight duplicate-whist boards were played through once before any records were taken in order that the attention of the subject might be completely absorbed in the game. In other words, records were taken only in connection with the duplicate round. The score was read at the end of each hand. The experiment required the help of three persons besides the four players. The first assistant marked on the graphic record the letters and numbers called out by the other two. The second assistant called the numbers of the hands and of the tricks as they fell, noting on a record sheet of her own whether the subject's side took the trick or not. The third assistant was always a person who had played often enough with the subject to make pretty shrewd inferences in regard to her mental processes under given circumstances. This assistant sat where she could both see the subject's hand and watch all the plays. When she made some inference in regard to the subject's state of mind, she indexed her note with a letter which she called to the first assistant who marked it on the graph. When a hand was played out, the third assistant checked doubtful in-

ferences by reference to the subject. In general, however, the subject was left to enjoy her game unmolested by requests for introspection. The whole value of the method depends on the fact that both subjects took the game seriously. Its glaring defect is in the fact that the third assistant could not possibly take account of the complexity of the subject's feelings. Often, for example, in spite of incidental triumphs or misfortunes, a tendency toward anxiety or exhilaration would run through the playing of a whole hand or succession of hands.

It is now in order to outline the respiratory changes studied. These are (1) changes in regularity, (2) changes in rate, (3) changes in the depth or amplitude of the thoracic phase of the respiration, and (4) changes in the length of the expiratory pause. The records have never been worked over to determine changes in the rapidity of the respiratory act itself or in the relative rapidity of inspiration and expiration. Moreover, the attempt at recording changes in the depth of abdominal breathing side by side with changes in the depth of thoracic breathing was abandoned simply because the manipulation of two tambours and the study of two sets of tracings required more time than the experimenters[1] could give to the investigation.

The pneumograph employed was the Sumner belt. The kymograph revolves upon a horizontal axis and is six inches in diameter and eighteen inches long. During most of the experiments, the revolution-time was about four minutes. During the music experiments, the last group to be performed (although, on logical considerations, it is numbered three), this time was about three and one-third minutes. The time-marker was a magnet-pen (Sumner's) which registers seconds on the kymograph side by side with each pneumograph tracing. In all the experiments, except in those of Group 3 and a part of Group 5, the writing arm of the tambour was tipped with a pointed strip of manila paper and measured about six inches; in these later experiments the lever was less than three inches long and was tipped with a fine straw. A single sheet of smoked paper held cross-wise from six to seven pneumograph-tracings each with its parallel time-record. The instruments were not moved in the horizontal plane with the aid of a carriage but were clamped to a horizontal rod in such wise that although they could easily be raised or lowered, they did not slide in a line parallel to the drum. After practice, however, the experimenters succeeded in moving the whole standard and readjusting the writing points so quickly that a twenty-minute record could be secured virtually unbroken.

The pneumograph belt used with the dogs was made to order on the model of his other belts by Mr. Horace E. Sumner,[2] of the Harvard

[1] See note, page 261.

[2] A drawing of the Sumner pneumograph may be found in Titchener's "Experimental Psychology," Inst. Man. Qual., p. 184.

Physiological Laboratory. It was designed for use with any animal in size between a cat and a thirty pound dog. It is eight inches long without stretching, is made of lighter weight rubber than the ordinary belt and has a more flexible spring. A belt of this size, if desired for use with animals as small as a fifteen pound dog, should not have the flat metal braces at the ends; these pieces fail to serve their purpose and they annoy the animal.

The kymograph is turned by an alternating-current motor and the speed is reduced by a system of pulley-wheels. The change of speed between the earlier and the later experiments was due to a permanent change in the light current utilized. In the earlier experiments the circuit of the magnet-pen was made and broken by Lough's electrically actuated pendulum; in the later experiments by a mercury-contact metronome (Maelzel's).

The breathing-rate per minute was computed with the aid of the second marks for every tracing, long or short, which had separate significance. Table 3 is made up of averages of rates so determined. On the other hand, changes in form as distinct from the rate of breathing, that is changes in regularity, changes in the depth of respiration, and changes in the length of the expiratory pause, were determined not by any system of count or measurement but simply by the careful inspection of two experimenters who verified each other's conclusions. A numerical character is introduced into these data only by the count of cases or "observations." An attempt at genuine measurement with triangle and rule in experiments at once so extensive and so rough would be a glaring instance of misplaced accuracy.

In the first two groups of experiments, as a standard of reference for determining the changes which took place in the rate and form of breathing during an attention-stimulus, a normal tracing was taken before each separate stimulus and this tracing ran into the stimulus-tracing on the kymograph without fresh adjustment of the apparatus. In these experiments, therefore, changes in the form and rate of breathing during stimulation mean changes from the form of the normal preliminary tracing taken in every case. Each stimulus-record was also followed by a tracing taken under conditions which were normal except for the possible after-effects of the stimulus. Breathing-rates determined from these tracings are called "reaction-rates" or "relief-rates." Little use has been made of the reaction-tracings in determining the normal form of breathing. In the "revery-tracings" of the first two groups of experiments, and in all the tracings of the last three groups, modifications of the normal form and rate of breathing have been determined much less accurately and satisfactorily. In the revery-tracings, in which no stimulus was given, changes of form were determined by comparing the second half of the tracing with the first. The character of the average rate was

determined by comparison with the average normal rates of the students or children. In the music experiments in which many of the stimuli lasted over fifteen minutes, the standards of reference are normal tracings taken at the beginning of each sitting. Two or three music-tracings have but one such standard. The reason for this unsatisfactory procedure was the desire to minimize the subject's self-consciousness and thus to get as much æsthetic effect out of the music as possible. In the whist experiments, the standards are still less satisfactory since they consist simply of groups of tracings taken at about the same time as the stimulus-tracings, but at different sittings. In the tracings obtained from the dog P., changes are always in the direction of more rather than less normal breathing. None of the tracings were assumed to constitute a standard of reference. The whole mass of tracings was simply considered together to determine the modifications of breathing which took place as fear subsided. The tracings obtained from A., have not been studied with reference to changes in form.

Before passing to the presentation of results it remains only to note the massing of individual results. Except for the experiments on the whist players and the dogs, the results of whole groups of subjects are counted together as instances of the different varieties of attention. When an individual furnished more than one instance of a given variety of attention, these observations are counted each as one, quite as if they had been furnished by different subjects. For example, the average breathing rate for the students under normal conditions, that is, conditions of low and unstable attention, is obtained from 505 observations furnished by 104 different individuals. The justification of this procedure is the fact that the results from unpracticed subjects vary as widely for the same individual as for different individuals. As regards variation in rate, results from individual subjects have been averaged separately a sufficient number of times to offer ample illustration[1]

[1] In illustration of this statement, the following figures may be taken from the music experiments. All subjects from whom over fifteen normal tracings were taken are included. The tracings cover periods from 30 seconds to 3⅓ minutes in length. The rates are computed per minute.

All tracings of rate faster than average normal.	Cases	164	Av. rate 20.7	M. V. 1.5
All tracings of rate slower than average normal.		184	14.1	2.2
Subject C.		24	12.8	2.0
" D.		17	18.6	3.2
" N.		18	15.1	1.4
" P.		27	20.3	3.7
" S.		23	19.8	.9
" T.		27	18.2	1.3

of this statement. As regards form, the assertion cannot be proved without photographs of the tracings.

The writer has now attempted to state the specific purpose and point of departure in this investigation of the correlation of changes in breathing with changes in attention, to outline the changes in attention which have been taken into account with the expedients used to control them, to enumerate the changes in breathing which have been studied, and to indicate the apparatus used in registering them and the method by which they have been given numerical expression. The conclusions will now, for the convenience of the reader, first be tabulated and afterwards be taken up in detail with such numerical evidence as may exist for them.

The following conclusions may be drawn:

I. In regard to the form of breathing:

1. When the stability of attention increases
   (1) The length of the expiratory pause tends to increase in regularity, but
   (2) The depth of breathing does not tend to increase in regularity under all the experimental conditions.
2. When the stability of attention decreases, both expiratory pause and depth of breathing decrease in regularity.
3. When the degree or level of attention rises
   (1) The expiratory pause tends to decrease.
   Exception: If attention is strongly expectant, the expiratory pause tends to increase.
   (2) Breathing tends to become shallower.
   Exceptions: In distinct pleasantness breathing tends to become deeper.
   In extreme animal fear breathing becomes deeper.
4. When the degree or level of attention falls either below the normal or after conscious strain
   (1) The expiratory pause becomes shorter than the normal.
   (2) Breathing becomes deeper than the normal.

II. In regard to the rate of breathing:

1. When the level of attention rises
   (1) Breathing which before the stimulus has been slower than the average normal tends to be accelerated.
   (2) The rate of breathing which has been faster than the average normal is much less affected than the rate of slow breathing and may even be retarded.
   Exception: In the case of very stable attention with the consciousness of strain (mental application), breathing, whatever its rate before the stimulus, tends to become decidedly faster.

2. When the level of attention falls either below the normal or sharply after great strain, breathing tends to become faster as one of the symptoms of relaxation.
3. When the stimulus comes to an end, breathing tends, unless the affective disturbance persists, to return to the rate which it exhibited before stimulation.

By far the most constant of these changes is the acceleration of slow breathing with a rise in the attention-level. Perhaps the next most constant change is the variation in the regularity of the length of the expiratory pause with variation in the stability of attention. Whether any of the changes deserve the adjective "constant," the reader must decide for himself from the figures. The presentation of this numerical evidence is now in order.

Tables 1 and 2 present all the statistics obtained from the first two groups of experiments in regard to changes respectively in the form and in the rate of breathing with changes in the nature of attention. Table 3 is made up of averages of rate-counts for tracings taken under different conditions of attention in the first two groups of experiments. The results of the third group of experiments are excluded from the tables because the standards of normal breathing obtained in this group are unsatisfactory in determining changes under stimulation. The results of the fourth group are excluded for the same reason and also because they are of an individual character and thus not comparable with the massed results of many different subjects. It should be noted in passing that nearly all the observations in each set of cases in the tables were obtained from different individuals. However, virtually all the cases of memorizing were obtained from subjects who also furnished cases of arithmetic, and more than one kind of memorizing was often required of the same subject. Out of the 154 cases of mental application in the students, 78 were cases of arithmetic and 76 cases of memorizing.

It will be convenient in discussing the conclusions summarized above to state severally in connection with the various inferences which may be drawn from the tables such contradictory or corroborative evidence as may be drawn from the results not included in the tables. Changes in form will be discussed before the changes in rate. Thus the first data discussed will be those of Table 1.

In view of the account of experimental conditions already given the only column of this table which seems now to require explanation is the column headed "Number of Observations." In the first group of experiments, the later observations of high-level attention have been singled out from the total number and represented separately. This was done because they

TABLE I.

Changes in the Form of Breathing with Changes in the Degree and Stability of Attention.

Group of Experiments.	Change of Attention.			Number of Observations.		Changes in Regularity of				Changes in Amount of			
		Nature.				Breathing Amplitude.		Expiratory Pause.		Breathing Amplitude.		Expiratory Pause.	
	Condition.	In Degree.	In Stability.			Increase Cases %	Decrease Cases %	Increase Cases %	Decrease Cases %	Increase Cases %	Decrease Cases %	Increase Cases %	Decrease Cases %
1	Mental arithmetic and memorizing.	Increase	Great increase	Later	43	65.1	34.9	65.1	30.2	27.9	72.1	——	93.0
Subjects:				Total	154	22.7	17.5	42.2	14.9	15.6	33.1	8.4	53.2
Students.	Listening to pleasant reading.	Increase	Increase	Later	19	31.6	52.6	36.8	42.1	21.1	68.4	52.6	26.3
				Total	39	20.5	33.3	28.2	20.5	28.2	43.6	41.0	33.3
	Listening to unpleasant reading.	Increase	Increase (Great variations.)	Later	27	37.0	55.6	59.3	40.7	22.2	70.4	18.5	81.5
				Total	52	40.4	34.6	38.5	32.7	26.9	51.9	34.6	48.1
		Decrease	Increase	Total	45	24.4	71.1	51.1	33.3	73.3	22.2	22.2	62.2
2	Mental arithmetic,	Increase	Increase		49	44.9	46.9	65.3	32.7	34.7	63.3	61.2	38.8
Subjects:	Entertainment,	Increase	Great increase		59	57.6	39.0	79.7	15.3	72.9	25.4	61.0	39.0
Children.	Annoyance,	Increase	Decrease		52	21.2	78.8	25.0	67 3	38.5	61.5	46.2	51.9
	Revery so-called= entertainment.	Increase	Increase		51	56.9	39.2	78.4	15.7	78.4	21.6	62.7	33.3

were made at the same period and by precisely the same methods as the observations of revery in the students and of all the attention-changes in the children. On the other hand, the earlier observations of high-level attention in the students were made earliest in the course of this study. But in working over the earliest tracings, relatively inconspicuous changes in form were left out of account. If, therefore, the figures for the total number of observations of great attention in the students, that is, the totals printed in heavy-faced type, be compared with the other totals in the table, the face-value of the figures would indicate that the breathing-changes in question were more common in the children than in their elders, and more common when the students fell into revery than when their attention changed in other ways. Neither of these indications is warranted by the facts. Only the figures in the lighter type may be compared with one another if the point in question is the number of times the breathing changed *in any way* in depth or regularity or expiratory pause with a given change in attention. It should also be noted in passing that the stimuli first employed were less effective than those later employed. For instance, arithmetic is more effective than is memorizing in securing great and stable attention. But of the 43 later cases of mental application in the students all are cases of arithmetic, whereas out of the 111 earlier observations 76 are cases of memorizing.

The most striking feature of the table is the approximation of the figures in the bottom line with those in the next line but one above. On the showing of their respiration, the children either were not entertained by the devices of the experimenters or else they did not fall into genuine non-emotional revery. The first of these suppositions was rendered incredible by their behavior, and, therefore, the second has been adopted in construing the results. One should also observe the justification furnished by the figures in this table for the assumption that when the children were entertained their attention was stable. The figures for the children in the third line from the bottom should be compared with those for the students in the first line of the table. In mental application in the students attention was by hypothesis stable in the highest degree.

As regards *changes in the regularity* of breathing, the following observations may be made upon the figures: There are eight total sets of cases in the table. It is practically certain that in one of these sets, the cases of annoyance in children, attention became in general exceedingly unstable. In this set of cases, the expiratory pause became more irregular in 70% and the depth of breathing in 80%. In each of the seven other sets, it is probable that attention became more stable in the majority

of cases. In all of these sets save one, the length of the expiratory pause tends unequivocally to become more regular. Moreover, the tendency toward greater regularity in the expiratory pause is most pronounced in exactly those sets of cases in which it is most certain that attention became more stable, namely, in mental application in both classes of subjects, and in both kinds of pleasurable absorption in the children. The exception to the rule is constituted by the cases of attention to pleasant reading. In the later observations the pause tends to become more irregular, and in the total number of observations the tendency toward greater regularity is slight. The irregularity is doubtless accounted for by respiratory movements verging toward laughter. It seems best, therefore, to exclude this class of cases from consideration as regards changes in the regularity of either the expiratory pause or the amplitude. On the whole, the figures for the expiratory pause offer a rather neat confirmation of the conclusion that breathing becomes more or less regular as attention becomes more or less stable.

So much cannot be said of the figures for the amplitude. It is clear that the amplitude tends to become more irregular when attention becomes less stable than the normal. It is true also that the amplitude tends to become more regular in three out of the four sets of cases in which it is most certain that attention became more stable. It is not, however, by any means clear that under "all experimental conditions" the amplitude becomes more regular when attention becomes more stable. Witness the cases of revery and the later and more perfect observations of attention to unpleasant reading in the students and also the cases of mental application in the children. In the interpretation of these cases, we fall into a dilemma. *A priori*, it would be easy to object that perhaps the effect of mental arithmetic upon the children and of unpleasant imagery or idleness upon the students was not to secure stable attention. Yet in these three sets of cases the expiratory pause did become more regular. We must suppose, therefore, either that the increase in the regularity of the expiratory pause is meaningless or else that the depth of breathing became more irregular in despite of the fact that attention became more stable. The writer makes the second supposition.

The evidence furnished by the other groups of experiments is now in order. The results of the music experiments are of doubtful validity. Out of 155 stimulus-tracings in which modifications of regularity were carefully studied, the expiratory pause became less regular than the corresponding normal pause in 25.2% and more regular in 14.2% and the amplitude became less regular than the corresponding normal amplitude in 24.5% and more regular in 12.9%. Although the method by which

these modifications were determined was loose and inaccurate, yet it is fairly evident that the tendency was toward irregularity. The length of the pause was probably affected by variations in the loudness of the music. The writer conjectures that the breathing rhythm was also somewhat affected by the music rhythm.[1] These tracings all belong to the period in which long compositions were played on the organ. Had these same curves been correlated with the hymn-tunes, one might suppose that especially in subjects of a kinæsthetic turn of mind, the irregularity was due to singing-movements imperfectly suppressed. In the somewhat similar experiments of Binet and Courtier upon a single subject, a similar irregularity was found. These writers conjecture that it is "le développment des idées et des sentiments qui trouble la respiration, tout en tenant compte des effets spéciaux dus à la mélodie et à l'harmonie."[2]

In the whist-experiments, changes in the expiratory-pause were not studied at all. Fortunately, however, as regards the regularity of the amplitude, the experiments are more satisfactory than the music experiments, at least on the face-value of the figures. Inferences in regard to changes in regularity are very uncertain since each phase of attention was assumed to last only a very short time, sometimes only ten or twelve seconds. The tracings are divided, therefore, simply into tracings which are as regular as the normal, tracings which are slightly irregular and tracings which are very irregular. The results may be sketched as follows: With the subject G. (the writer), out of 18 tracings taken during "study," that is, reflective attention to a given hand, 66.7% are as regular as the normal; out of 15 tracings taken during "suspense" or "anxious attention," 53.3% are as regular; out of 9 tracings taking during "relief," 66.7% are as regular; on the other hand, out of 59 available tracings taken during gratification or "pleasure," 67.8% are very irregular; and out of 50 tracings taken during "chagrin," 48% are very irregular and 16% slightly irregular. With the subject H., out of 21 study-tracings, 61.9% are as regular as the normal; out of 35 available suspense-tracings, 74.3% are as regular; out of 20 relief-tracings, 45% are as regular as the normal but 35% are very irregular and 20% slightly irregular; out of 68 available pleasure-tracings, 82.4% are very irregular; and out of 78 chagrin-tracings, 74.4% are very irregular. In view of the unsatisfactory nature of the standards of normal breathing, of the fragmentary character of the tracings, and of the guess-work by which the subject's

[1] The curves have not been studied with special reference to this point.

[2] L'Année Psychologique, 1896, pp. 114-115.

states of mind were determined, the correspondence between these two sets of figures is remarkable. Only the figures for relief indicate any divergence of tendency and here the number of observations upon the first subject is very small. Certainly the tendency in emotional excitement toward greater irregularity in the depth of breathing is too heavily marked to be overlooked.

Only the tracings obtained from the spaniel P. remain to be discussed. One hundred tracings were secured as long as the full circumference of the drum. Fifteen of these curves were so broken by the movements of the dog as to be thrown out. The remaining eighty-five are divided thus: Dog greatly frightened, trembling violently and sometimes panting, with occasional yawning inspirations, 10; dog moderately frightened and trembling slightly, 27; dog slightly frightened and trembling at intervals, 22; dog quiet and drowsy, 18; dog asleep, 8. This trembling affected the spaniel's hind-quarters chiefly, and did not seem, of itself, to produce gross irregularities in the tracings although it sometimes gave a wavy appearance to the inspiration-line. Both the amplitude and the expiratory pause were studied in these tracings. The results are as follows: When the dog was in a state of repose, whether she was awake or asleep, both the amplitude and the expiratory pause were strikingly regular.[1] Even out of the 22 curves taken when the dog was slightly frightened, the amplitude is very regular in 11 and the pause in 14. On the other hand, out of the 27 tracings taken when the dog was moderately frightened the amplitude is very irregular in 18, and out of the 10 tracings taken when she was badly frightened it is very irregular in all. The irregularity produced by fear in the expiratory pause is much less marked. Out of the 27 tracings of moderate fear, it is very irregular in 13 only, whereas in 7 out of the 10 tracings of great fear it is eliminated and is regular in the sense of regularly failing to appear. These facts close the evidence in regard to regularity.

It will be remembered that the positive assertion of the Angell-Thompson thesis, which it is the purpose of this investigation to verify, is that the correlation between regular breathing and stable attention and between irregular breathing and unstable attention is essentially constant. In making this particular assertion the writers do not distinguish between regularity of amplitude and regularity of expiratory pause. The results of the experiments here reported would seem to show, first, that the regularity or irregularity of the one does

[1] This great regularity is not exhibited by the tracings taken in repose from the spaniel A.

not imply the regularity or irregularity of the other; second, that the correlation between the regularity or irregularity of the expiratory pause and the stability or instability of breathing is "essentially" constant in human beings; third, that the amplitude tends in the large majority of cases to become irregular when attention becomes unstable; fourth, that the amplitude does not tend to become regular in all groups of cases in which the testimony or behavior of the subjects and the regularity of the expiratory pause indicate stable attention.

It will be remembered that MacDougall[1] found great irregularities in the depth of breathing correlated with mental application. This irregularity he attributed to the concomitant shallowness of breathing and to "periodically increased innervation due to incipient asphyxiation." For the cases here reported this explanation is insufficient. The breathing of both students and children tends to become shallower in mental arithmetic, but the breathing of the students tends to become more regular in depth and that of the children does not. Moreover, a study of the individual tracings from the students reveals no definite correlation between shallowness and irregularity of depth. MacDougall also suggests that irregularity during mental arithmetic may be due to a fluctuation in the intensity of the effort required. This explanation doubtless holds for the irregularity in some of our arithmetic cases. One must also take into account the tendency in some of the children to disobey orders and call out the result at each step in the process. None of these explanations, however, touch the irregularity in the revery-cases. Here thoracic breathing becomes noticeably deeper, and one is reminded of the assertion of Mosso that "when one does not attend closely, the diaphragm tends to become quiet and the thorax makes larger but irregular movements."[2]

For convenience, *changes in the absolute size of the amplitude and in the absolute length of the expiratory pause* will be discussed together. In the eight sets of cases in Table 1, we have all the four possible combinations of tendencies to change in these two features of respiration. In only one of the eight sets is the level of attention assumed to fall. These are the revery-cases. Here alone breathing (1) tends to deepen at the same time that the expiratory pause tends to become shorter. In all the other seven sets of cases the level of attention is assumed to rise above the normal. In three of them, breathing (2) tends to become shallower while the expiratory pause tends to

[1] The Physical Characteristics of Attention, *Psych. Rev.*, 1896, pp. 158-180.

[2] "Die Ermüdung," Quoted by Angell and Thompson.

shorten. Of these three sets, one is the group of mental-application cases in the students. Here we have exactly that shallow and rapid type of breathing which has been found by so many investigators[1] in correlation with mental effort or "voluntary" attention. Another of the three sets is that of the unpleasant-reading cases in the students. Here also attention probably increased in stability as well as degree, so that there was a certain kind of "mental application." The third set is that of the annoyance cases in the children. This result is in flat opposition to the finding of Binet that breathing deepens in fear, disgust, and anger. We have now taken up four of the eight sets of cases in the table. In two of the remaining four groups, breathing (3) tends to become shallower, whereas the expiratory pause tends to lengthen. These are the pleasant-reading cases in the students and the arithmetic cases in the children. Finally, we have the last possible combination of effects in the last two sets of cases, those in which the children were "pleasantly entertained." Here breathing (4) tends to deepen whereas the expiratory pause tends to lengthen. This last combination of effects must almost inevitably retard the breathing,[2] and is therefore in opposition to the results of Binet who found accelerated breathing and an abbreviated expiratory pause in fairly constant correlation with a rise in the attention-level.

Before theorizing on these combinations, it will be well to take into account the results not included in the table. Out of nine pain (pinching or pricking) experiments upon the students the breathing became noticeably shallow in eight. Out of the eight experiments in which unpleasant circumstances were voluntarily recalled, the breathing became shallow in five. This is the only unequivocal testimony as to tendencies toward changes in form which is furnished by the pain and voluntary-emotion experiments. In the music-experiments, modifications in the size of the amplitude and expiratory pause were not adequately studied. The figures for the pause are not worth giving. Out of the 155 tracings discussed under the head of regularity the amplitude was greater than the normal in 29% and less in 21.9%. In the whist experiments, as already stated, the expiratory pause was not studied at all. In regard to amplitude, the results may be briefly indicated as follows: In the study-tracings of the subject G., the amplitude was less than the normal in 50% and greater in 22.2%; in the suspense-tracings, it was less in 53.3% and greater in 20%; in the relief-

[1] Mentz, Delabarre, Binet and Courtier, Lehmann, Meumann and Zoneff, MacDougall.

[2] Theoretically, the relative rapidity of muscular contraction and relaxation must also be taken into account.

tracings (only nine in number) it was less in 22.2% and greater in 22.2%; on the other hand, in the pleasure-tracings, it was greater than the normal in 60% and less only in 8.3%, and in the chagrin-tracings it was greater in 46% and less in 24%. With the subject H. the amplitude was less than the normal in 47.6% of the study-tracings and greater only in 4.8%; in the suspense-tracings, it was less than the normal in 55.5% and greater in 13.9%; in the relief-tracings, it was less in 30% and greater in 15%; in the pleasure-tracings, on the other hand, the amplitude is greater than the normal in 34.8% and less in 15.9%; and in the chagrin-tracings, it is greater in 25.6% and less in 24.4%. The two sets of figures agree in showing a tendency toward shallower breathing in mental application and toward deeper breathing in pleasurable excitement. As the breathing in pleasure was more rapid as well as deeper than the normal, the expiratory pause was almost certainly shorter. The breathing of G. also tended to be deeper and faster in chagrin. This chagrin, be it noted, was not an exhilarating form of anger but was commonly an unpleasant mixture of disappointment and mortification.

Turning to the spaniel-tracings, one finds that in repose and in slight alarm, the dog P.'s breathing was very shallow with a long expiratory pause. In moderate fear, her breathing became still shallower and the expiratory pause was still longer as well as less regular. These tracings have a peculiar "thready" appearance. On the other hand, when she was intensely frightened her breathing deepened in every case and the expiratory pause was eliminated. As noted above, when P. was extremely frightened she often panted with lolling tongue and also yawned at intervals.[1]

There are strong resemblances between the tracings taken from the dog P. in extreme fear, the pleasure and chagrin tracings of the subject G., the pleasure and relief-tracings of the subject H., and the mass of revery-tracings taken from the students. In all these groups, the amplitude tends to deepen and to become more irregular and the expiratory tends to shorten. This deep and rapid breathing is the type which Binet considered characteristic of emotion. Probably most of the tracings of the whist experiments which are labelled pleasure or chagrin are really relief-tracings as well. Attention suddenly relaxed when the subject or her partner won or lost

[1] The same symptoms of fear have been noted under other circumstances in other cockers belonging to the writer. A. exhibits them in the railway cars. It should be noted in passing that A.'s normal breathing is not "thready" like P.'s. A.'s curves in their moderate depth, their comparative irregularity and brief expiratory pause resemble the tracings of a little child.

the crucial trick of a hand or succeeded or ignominiously failed in establishing a long suit. Attention in such cases may remain at a relatively high-level, but, in spite of the affective disturbance, there is, to the best of the subject G.'s self-observation, a distinct fall of level, a release from the tension of preceding moments.

For the unification of the various data in regard to the amount of amplitude and expiratory pause, the writer hazards the following conjectures: First, a given type of breathing, deep, irregular, and with little or no expiratory pause often characterizes the lapsing of effort or rather of those nervous conditions which keep attention stable at a high level and which sometimes result in the effort-consciousness. This panting breathing occurs in profound affective disturbance in which the stability of attention is broken up, in cases of sudden relief in which there is a sharp drop in the attention-level, and in cases of revery in which the attention-level falls very low. It may well be objected that this type of breathing is not that of sleep. But revery is neither effort nor sleep but a transition-state which may have different physical characteristics from either. It is impossible, however, to blink the fact that when the children were annoyed their breathing was shallower in the majority of cases and the expiratory pause longer in a large minority of cases (46.2%).

Second, when the level of attention rises, there is a general tendency for breathing to become shallower. This tendency may be part and parcel of the muscular inefficiency found in mental effort by MacDougall, and supposed by him to indicate "a reduction in the degree of reflex stimulation throughout the organism and inferentially a greater efficiency in the central nervous discharges." An exception to this general tendency is the deep breathing which, on the showing of Binet, often characterizes emotion. Setting aside the spaniel-tracings, the only exception which appears in these results is the deepening of breathing in marked cases of pleasure when attention still remains stable. In the large majority of each of the two sets of cases in which the children were agreeably entertained, the breathing deepened although the expiratory pause tended to lengthen. Thus deepened breathing would seem to be a concomitant both of relaxation without pleasure and of pleasure without relaxation. This supposition in regard to pleasure contravenes the opinion both of Binet and of Angell and Thompson. The writer is not prepared to press it. It is perfectly true that breathing did not tend to deepen when the students were entertained by reading. The students, however, were not half so well amused as the children. At any rate, one finds a striking contrast between the deepening of the chil-

dren's breathing when they were highly gratified and its shallowness when they were sharply annoyed.

Third, when the level of attention rises, the expiratory pause is shortened except when attention is strongly expectant. In expectation, which indicates a sort of suspended adaptation of the organism, the subject "pays breathless attention."[1] This view covers both the lengthening of the pause in moderate fear and in entertainment. Alike in the pleasant reading cases in the students and the entertainment cases in the children, the subjects were waiting for a *denouement*.[2] This conjecture is suggested by the remark of one of the student experimenters[3] that when the children were frightened or amused "the centre of interest was a 'What next?' involving physical restriction, rather than a glowing or indignant appreciation of the present, tending toward acceleration." It may be added that in the nut-cracker and varnish cases the pause lengthened notably,[4] whereas, when the boys were kissed, it shortened as conspicuously. This lengthening of the pause does not seem seriously to conflict with the results of Binet since he secured only a few cases of protracted expectation. Perhaps the lengthening of the pause when the children were doing mental arithmetic is not covered by this explanation. But aside from the probability that attention was in their case strongly expectant from step to step of the "sum," the length of the expiratory pause was undoubtedly modified by the tendency to speak at certain intervals.

Before one turns away from the consideration of changes in the form of breathing, it should be mentioned that on the showing of these experiments, changes in the amplitude, changes in the length of the expiratory pause, and changes in the regularity of either amplitude or pause all seem to be independent of one another. By no turning or twisting of Table 1 can any correlation between these modifications be made out. Moreover, the writer has worked out for the individual tracings of the first group of experiments a table of coincidences between the various changes and has reached a purely negative conclusion.

Changes in the rate of breathing must be treated with the utmost brevity. Tables 2 and 3 if clearly explained will speak

[1] Binet and Courtier recognize that after a shock, breathing may for the moment be retarded. This suspension they regard as an adaptation phenomenon. (*Op. cit.*, p. 81.)

[2] Expectation was much less marked during the unpleasant reading. Attention was held by the imagery presented.

[3] Miss A. S. Carlisle.

[4] In such cases there is often a marked inspiratory pause also or a peculiar "hump" or "foot-hill" in the inspiration line.

TABLE 2.

Changes in the Rate of Breathing with Changes in the Degree and Stability of Attention.

Group of Experiments.	Nature of Stimulation.	Slow Breathing.							Fast Breathing.						
			Increase.			Decrease.				Increase.			Decrease.		
		No. of Observations.	Total Cases %	Followed after Stimulation by Increase Cases %	Followed after Stimulation by Decrease Cases %	Total Cases %	Followed after Stimulation by Increase Cases %	Followed after Stimulation by Decrease Cases %	No. of Observations.	Total Cases %	Followed after Stimulation by Increase Cases %	Followed after Stimulation by Decrease Cases %	Total Cases %	Followed after Stimulation by Increase Cases %	Followed after Stimulation by Decrease Cases %
1 Subjects: Students.	Mental arithmetic, Memorizing,	56	80.4	12.5	66.1	17.9	12.5	3.6	98	74.5	10.2	62.2	22.4	6.1	16.3
	Listening to pleasant reading.	12	83.3	——	66.7	16.7	8.3	8.3	27	48.1	14.8	33.3	48.1	29.6	11.1
	Listening to unpleasant reading.	19	84.2	47.4	36.8	15.8	5.3	10.5	33	51.5	15.2	33.3	42.4	18.2	24.2
2 Subjects: Children.	Mental arithmetic,	28	82.1	21.4	50.0	14.3	7.1	7.1	21	42.9	9.5	33.3	57.1	33.3	19.0
	Entertainment,	24	54.2	20.8	33.3	37.5	12.5	20.8	31	35.5	12.9	19.4	61.3	29.0	32.3
	Annoyance,	23	56.5	13.0	43.5	34.8	17.4	13.0	25	40.0	——	40.0	56.0	28.0	28.0

TABLE 3.

Breathing Rates Correlated with Different Kinds of Attention.

(*All rates are calculated per minute.*)

Group of Experiments.	Nature of Stimulation.	Slow Breathing.				Fast Breathing.			
		Rate for Preliminary Tracings.	Stimulus-Tracings.		Rate for Relief Tracings.	Rate for Preliminary Tracings.	Stimulus-Tracings.		Rate for Relief Tracings.
			Number.	Average.			Number.	Average.	
1 Subjects: Students.	No stimulus: Normal,	——	240	14.2	——	——	265	21.2	——
	No stimulus: Revery,	——	10	15.0	——	——	35	22.1	——
	Arithmetic,	15.7	25	20.9	17.2	21.9	53	23.9	21.0
	Memorizing,	16.1	31	17.9	17.1	22.2	45	23.3	22.1
	Pleasant reading,	15.8	12	17.8	16.9	21.2	27	21.3	21.6
	Unpleasant reading,	15.3	19	17.2	17.7	20.9	33	21.0	19.2
2 Subjects: Children.	No stimulus: Normal,	——	103	19.0	——	——	99	27.1	——
	Arithmetic,	19.2	28	21.4	19.5	26.9	21	26.6	24.8
	Entertainment,	18.7	24	20.7	19.8	26.2	31	26.1	26.1
	Annoyance,	18.9	23	22.7	19.1	27.8	25	26.6	22.9

for themselves. The detail which it is most important to explain is the division of the observations into cases of slow and cases of fast breathing. This division was made because in looking over the rates for the different conditions of attention it appeared that the mean variation would be enormous. When the division was actually made and the two sets of cases studied separately, it appeared that the rates were modified differently under stimulation. This showing, however, was the result of making the division and not the reason for doing it.

The division was made in this way: The arithmetical mean was found for all the "normal tracings," short or long, of each class of subjects. The normal tracings from the students are 505; the average rate is 17.9 inspirations per minute; the mean variation is 3.5. The normal tracings from the children are 202; the average rate is 23.1; the variation is 2.5. Each set of observations which included both a preliminary tracing and a stimlus tracing was classed as a case of fast or slow breathing according as the rate of the *preliminary tracing* did or did not exceed the average normal rate for the whole class of subjects, young women or children. In the revery experiments, each tracing is classified according as its total rate did or did not exceed the average normal.[1]

Three other details should be explained: (1) The mean variations from the averages in Table 3 have been omitted merely to save space. The ordinary variation is two and some tenths. (2) For the sake of saving space in Table 3, the number of rate-counts averaged is given only in connection with the averages of the stimulus-rates. In a few cases the relief-tracing corresponding to a stimulus tracing is lacking, and in the experiments in memorizing syllables and poetry one of the preliminary tracings averaged as such answers to two stimulus-tracings. The tracing interpolated between the two stimulus-tracings is taken account of in Table 2 but cannot properly be averaged either as a true preliminary or as a true relief-tracing.[2] (3) In Table 2, the percentages in the light-faced type pertain to the same total numbers of observations as the percentages in the heavy-faced type. To illustrate from the first line of the table, out of 56 cases of slow breathing the rate rose during arithmetic or memorizing in 45 cases or 80.4%. It rose during stimulation and continued to rise afterwards in 7 cases or 12.5% of 56; it rose to fall again afterwards in 37 cases or 66.1% of 56 and so on.

Turning to the significance of the figures in Tables 2 and 3, one may make the following cursory observations: First, slow breathing strongly tends to be accelerated as the level of attention rises. This tendency is paramount in all groups of cases although, in the entertainment and annoyance cases of the children, it is opposed by the tendency already noted for the expiratory pause to lengthen in expectant attention. Second, in

[1] The writer now sees that it would have been better to find the "central value" rather than the arithmetical mean and to draw the division-line at this point. However, the experiments really do not seem at best precise enough to justify the doing of all the intricate rate-work over again.

[2] See page 271.

rapid breathing the tendency for the expiratory pause to lengthen in expectant attention is so weighty as sometimes to overbalance any tendency toward acceleration which may accompany the rise in level. Thus both in slow and in rapid breathing, high-level attention, if expectant, produces a disturbance of type, in one case accelerating and in the other tending to retard. Third, in mental work on the part of the students, the tendency toward acceleration is marked in both types of breathing. Here attention, though, strained, was practically non-expectant. Fourth, in the students' arithmetic cases, the average amount of acceleration is much larger in both types of breathing than it is in any other set of cases from either class of subjects. (See Table 3.) Fifth, if the rate of breathing rises during stimulation, it tends to fall again afterwards, and if it falls, it tends to rise again afterwards. The exceptions to this rule, save for the few arithmetic cases, may be explained on the suppositions that the affective disturbance often persisted after the stimulus which occasioned it was supposed to have come to an end, and that in the memorizing experiments the students indulged in mental rehearsals during the relief-tracings. The fact that the rate tends to rise again afterwards when it falls during stimulation militates against the Binet and Courtier supposition that the fall after rise is a fatigue phenomenon.[1] It seems rather to be a lapsing of disturbance. Sixth, in the relaxation of revery, breathing is slightly more rapid than the normal. (See Table 3.) It may well be asked why, if this acceleration is due to the relaxation, we do not find acceleration in all the so-called "relief-tracings." The answer is that acceleration does not necessarily accompany relaxation in the sense of a return to the ordinary attention-level, but that it tends only to accompany relaxation in the positive sense of a fall below the normal level or of a sharp fall accompanied by the specific organic relaxation-consciousness.

To bring this long presentation of experimental results to an end, it remains only to add the data on rate-changes not included in the table. In the pinch-and-prick experiments in which the threat to hurt produced strong apprehension, slow breathing was considerably accelerated and rapid breathing was enormously retarded. Rapid breathing was in two cases suspended as long as the pinch lasted—upwards of ten seconds. If there were no mental expectation after a pain began, there was at least a difficult adaptation. It may be added here that the figures for the nut-cracker experiments, in which the children were frightened, would have made still lower the annoyance-average for rapid breathing in Table 3 had it not been for

[1] *Op. cit.*, pp. 52, 53.

a few cases of enormous increase in the experiments in which the boys were kissed. In one of these cases the stimulus-rate rose to 50.8 inspirations per minute. The average for rapid breathing is in the 13 nut-cracker cases, 24.8; in the 9 kissing cases it is 31.4.

In the music-tracings, the average for rapid breathing is slightly below the normal average for rapid breathing, and the average for slow breathing slightly above the normal average for slow breathing. As nothing can be said about the size of the expiratory pause in these tracings, the fall in rapid breathing cannot be explained. Here ends the evidence from massed results. As a whole, the rate-data tally exactly with the finding of Delabarre that persons who naturally breathe slowly show a much greater tendency toward acceleration when their attention is engaged than do persons who breathe rapidly.[1]

Only the evidence from the whist and dog experiments now remains to be added. Both subjects in the whist experiments breathe very rapidly under normal conditions and breathed throughout these experiments faster than their normal rate. G. breathed most rapidly in relief (24.7 inspirations per minute) and next rapidly in chagrin. H. breathed most rapidly in the cases labelled suspense (26.3 inspirations per minute), a fact which, so far as it goes, cuts straight across the expectation-theory advanced above. In these cases, however, her attention was probably at its very highest level.

For the dog P. the rate-averages are as follows: Great fear, 17.5 inspirations per minute; moderate fear, 14.3; slight fear, 13.9; waking repose, 10.9; sleep, 11. This acceleration in fear can scarcely be held to conflict with the expectation-theory since such fear in a dog, like the most overwhelming fear in human beings, is not definitely expectant. As a matter of fact, in moderate fear P.'s expiratory pause lengthened and the acceleration is due to the shallowness of her breathing. The mean variations from these averages for P. are not larger than the variations from the averages given in Table 3. It is probable, however, that the pressure of the belt tended to retard the dog's breathing. When A. is wearing the belt, her breathing rate varies from 10 to 40 inspirations per minute. Yet the average natural breathing rate of A. and of another young, but full-grown cocker now owned by the writer, is about 22 inspirations per minute when sitting awake and alert upon the lap, and about 18 or 19 inspirations when asleep.

It will be remembered that the negative assertion of the Angell-Thompson thesis is that the correlation between more and less regular breathing and more or less stable attention is

[1] Revue Philosophique, Vol. XXXIII, pp. 639 ff.

the *only* essentially constant correlation between respiration and consciousness. Such as they are, the results of this investigation tend to show that this formulation, like its historical predecessors in the same field, is too simple. The acceleration of slow breathing when the level of attention rises is essentially constant, the acceleration and deepening of breathing in relaxation is essentially constant, and the lengthening of the expiratory pause in expectation is significantly constant.

In conclusion, the points at which the results fail to fall into line with those of Binet and his co-workers may be indicated. Binet recognizes two types of breathing as variations from the normal which are produced by mental activity; first, the rapid, shallow breathing of intellectual work, and second, the rapid, ample breathing of emotion. This investigation reveals many instances of these types. In conflict, however, with the thesis of Binet it presents many instances of shallow breathing in emotion, of continuously retarded breathing in mental activity, and of rapid and ample breathing in relaxation.

On the whole, the writer is left in doubt as to whether the Angell-Thompson thesis or the Binet thesis, both alike too simple, can better be fitted into the facts. A suspicion also remains that the significance for respiration of pleasantness and unpleasantness may recently have been under-rated.